

Highly Ionized Envelopes of High Velocity Clouds

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Abstract.

We present recent results on highly ionized gas in Galactic High-Velocity Clouds (HVCs), originally surveyed in O VI [1]. In a new *FUSE/HST* survey of Si II/III/IV (Shull et al. 2009) toward 37 AGN, we detected Si III ($\lambda 1206.500 \text{ \AA}$) absorption with a sky coverage fraction $81 \pm 5\%$ (61 HVCs along 30 of 37 high-latitude sight lines). The Si III ($\lambda 1206.500 \text{ \AA}$) line is typically 4-5 times stronger than O VI ($\lambda 1031.926 \text{ \AA}$). The mean HVC column density of perhaps 10^{19} cm^{-2} of low-metallicity ($0.1 - 0.2 Z_{\odot}$) ionized gas in the low halo. Recent determinations of HVC distances allow us to estimate a total reservoir of $\sim 10^8 M_{\odot}$. Estimates of infall velocities indicate an infall rate of around $1 M_{\odot} \text{ yr}^{-1}$, comparable to the replenishment rate for star formation in the disk. HVCs appear to be sheathed by intermediate-temperature gas ($10^{4.0} - 10^{4.5} K$) detectable in Si III and Si IV, as well as hotter gas seen in O VI and other high ions. To prepare for HST observations of 10 HVC-selected sight lines with the *Cosmic Origins Spectrograph* (COS), we compile *FUSE/STIS* spectra of these ions, plus Fe III, C III, C IV, and S IV. Better constraints on the physical properties of HVC envelopes and careful treatment of HVC kinematics and infall rates should come from high-quality (S/N ≈ 30 -40) COS data.

Keywords: Galactic gas; High velocity clouds

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A BRIEF HISTORY OF HVCS

High Velocity Clouds (HVCs) were first detected in H I 21 cm emission by [2]; quasar sight lines showed emission at high velocity. Until the last few years, studies of these objects were unable to determine their distances, and therefore masses. There has been much debate about their composition, origin, and other basic features. HVCs are characterized by anomalous velocities with respect to Galactic rotation, with $|v_{LSR}| > 90 \text{ km s}^{-1}$. Since 1963, HVCs have been detected in O VI, C IV, Si IV, and various low ions [see 1, 3, 4, 5]. The presence of both low and high ions in HVC sight lines may suggest shock ionization as gas falls into the disk [4, 5].

RECENT PROGRESS

Shull et al. (2009) [6] find Si III to be a highly sensitive detector of HVCs (Figure 1). Along several of the 37 sight lines in their study, they find several small cloud components, partly because Si III $\lambda 1206$ is typically 4-5 times stronger than O VI $\lambda 1032$. The mean column density in their sample is $\langle \log N_{Si\ III} \rangle = 13.44 \pm 0.21$. Using the photoionization code Cloudy, they constrain the mean photoionization parameter to be $\langle \log U \rangle = -3.0 \pm 0.2$. This suggests mingling of low and high ions due to shock-

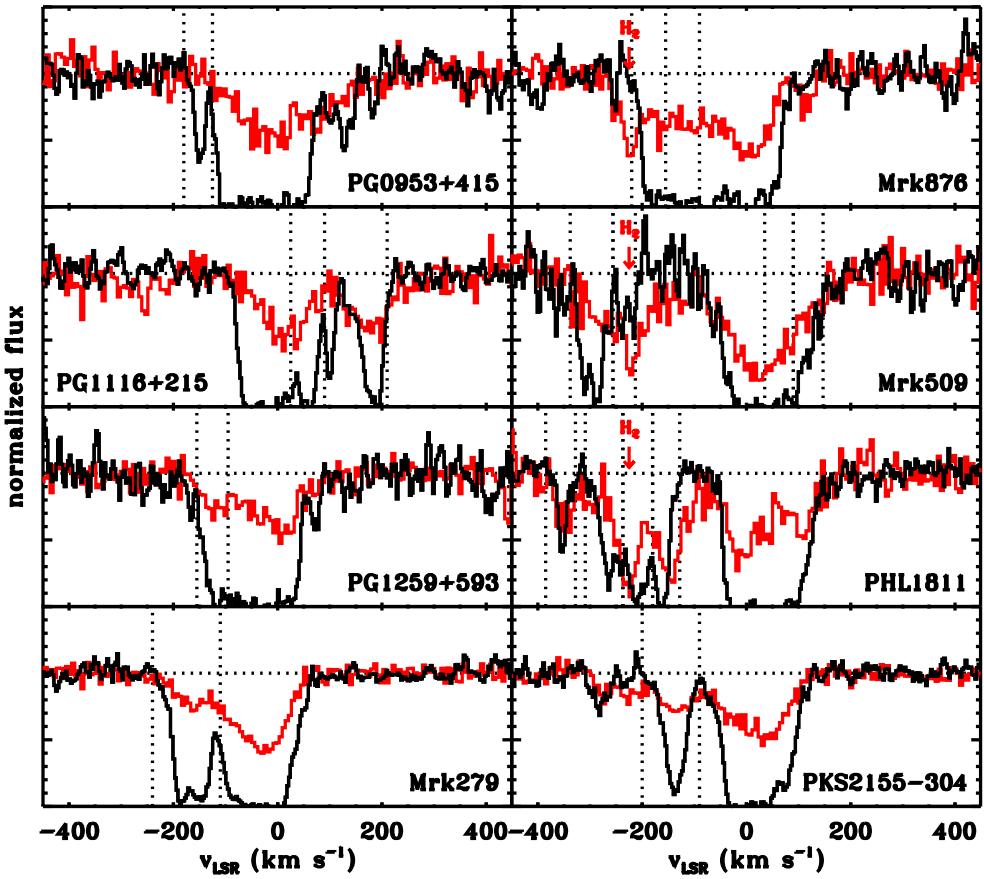


FIGURE 1. Comparison plot of several sight lines from Shull et al. (2009) [6] displaying the difference between the sensitivity of O VI ($\lambda 1032$, red/gray) and Si III ($\lambda 1206$, black). Interstellar H₂ lines are marked.

ionization, as gas falls through the Galactic halo, with a low ion cloud core shielded inside a hotter envelope.

The distance to HVC Complex C, an extensive cluster of sight line detections covering ~ 1600 square degrees on the sky, has been determined by [7] to be 10 ± 2.5 kpc. [8] detect HVCs at similar altitudes around M31. If this is a characteristic distance for most HVCs, this means they constitute a total mass reservoir of $\sim 10^8 M_\odot$ and have an infall rate on the order of $1 M_\odot \text{yr}^{-1}$. HVC infall may be sufficient to replenish star-forming gas in the Galactic disk. The source of the gas is still not well constrained; however, [4] have found that HVCs have low metallicities, $\approx 0.1\text{-}0.2 Z_\odot$, which points to mixing of primordial and Galactic gas.

CURRENT AND FUTURE DATA: DETECTION IN HIGH IONS

The goal of our research will be to use accurate kinematics and high S/N spectroscopy to determine mass infall rate and ionization states of the HVCs. The *Hubble Cosmic*

Origins Spectrograph (COS) will observe 10 sight lines with O VI-selected HVCs. Over the course of 28 orbits, we will obtain spectra with $S/N \approx 30\text{--}40$. In preparation, we have compiled data from *FUSE* and *Hubble STIS*. All 10 sight lines have O VI data from *FUSE*, but only a few have STIS data. The sight lines selected include some well-studied targets, such as Mrk 876, as well as some sight lines that currently have only low-S/N data, such as ESO 265-G23.

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